SOME STATISTICAL PICTURE OF MAGNETIC CP STARS EVOLUTION

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ABSTRACT. We discuss some statistical results on the evolution of magnetic CP stars in the framework of the supposition about their binary nature.

Key words: star, magnetic chemically peculiar stars, evolution, binary stars, neutron star.

1. Introduction

It is well known that CP stars of upper main sequence can be divided on magnetic chemically peculiar stars (MCP stars or Bp-Ap stars) and non-magnetic (Hg-Mn stars and Am-Fm stars). Hg-Mn stars have temperatures more than 10 000 K, Am-Fm stars are cooler than 10 000 K. Some authors concluded that there exists a relationship between Hm-Mn stars and Am-Fm star (Adelman, Adelman A.S & Pintado, 2003).

MCP stars are overlapped with Hg-Mn stars in the region of the hot temperatures of HR diagram and with Am-Fm stars in the region of the cooler temperatures. Evolutionary state of chemically peculiar (CP) stars of upper main sequence is the subject of some working hypotheses and numerous debates. The new observational facts on these stars cause more and more questions. Some reviews of specialists include the list of unsolved problems concerning this problem. Thus, it should be stated that origin of CP stars is not completely understood at present.

The MCP stars show more complicated phenomena among CP stars (Rudiger & Scholz, 1988). Now we do not have a hypothesis that could explain an origin of anomalies of chemical abundances and the kinematics of MCP stars, as well as origin of their magnetic field. Some characteristics of MCP stars show that they do not support old ideas about chemical evolution. Some existing inexplicable facts (Gopka et al., 2004, Gopka et al., 2006) force us to suppose that MCP stars are binary systems consisting two intermediate-mass stars experienced mass transfer between the originally less massive star and its more massive companion in the state of pre-supernova explosion with mass near to $8M_{\odot}$. As a result, the MCP star is influenced by the supernova remnant (neutron star, NS) and some its properties are formed under this influence (Gopka, Ulyanov & Andrievsky, 2008a,b). Such a model is supported by the results of the numerous investigations of MCP stars from IR to X-rays observation. The evolutionary change of the MCP star properties with mass reflects the change of the system's mass ratio (both for visible and invisible neutron star companion, Gopka, Ulyanov, Yushchenko et al., 2010).

2. On the increasing of rotational period of the low-mass MCP stars in the framework of model MCP star binarity

For some MCP stars an intensive mass-loss from magnetic poles are known. As an example, for the helium-strong stars σ Ori E and HD 37017 Drake et al. (1994) estimated the mass-loss rate near 10^{-9} $M_{\odot}$ per year with observed significant outflow velocity of about 600 $km\ s^{-1}$. Such a phenomenon can be easily understood in our phenomenological model of MCP stars (see Fig 1.). Important consequence of this conclusion is supported by statistical results of an increasing of the rotational period for low-mass MCP stars.

Fedorova (1997) investigated the qualitative changes of the low-mass X-ray binary evolution. When the matter is accreted by the low-mass star, the hard radiation occurs. Fedorova is obtained the theoretical dependence of the size semi-major axis from the mass of companion for the X-ray binary (Fedorova 1997). The some part of the matter MCP star falls on to NS, and the some part matter is taken away by the magnetic star wind for the case of close binary system, into which enters MCP star and NS. This case is in the base of our assumption where the donor is MCP star and acceptor is NS.

When so-called Jeans mode conditions are realized

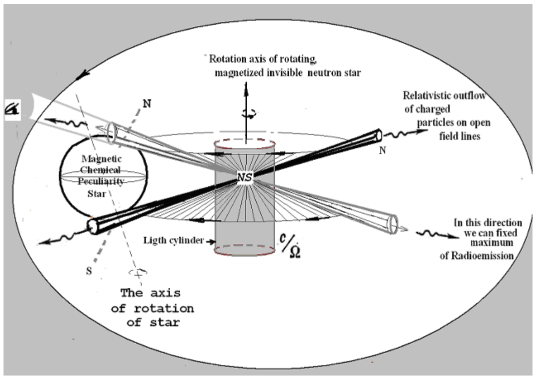

Figure 1: Schematic model of MCP star as a binary system with neutron star companion.

in the binary system, the change of the system semi-major axis (A_m) due to the mas-loss is given by the follow equation:

$$(\frac{dA_m}{dt})_{los} = \frac{-A_m}{(M_{star} + M_{ns})} \cdot (\frac{dM_{star}}{dt})_{los}, \qquad (1)$$

where A_m is the semi-major axis, M_{star} is the mass of the NS companion, M_{ns} is the neutron star mass.

Integration of this equation produces so-called Jeans invariant:

$$A_m \cdot (M_{star} + M_{ns}) = const. \qquad (2)$$

We simulated the dependence of the semi-major axis upon the mass of MCP star in an interval from $8M_\odot$ to $1.6M_\odot$. Than were founded that semi-major axis for dual stars with the MCP star masses in the range $1.6M_\odot$ - $8M_\odot$ and average NS mass near $1.35M_\odot$ is grow. The semi-major axis of the close binary system increases more rapidly for the MCP stars in combination with lower mass neutron star (Fig. 2).

This qualitatively confirms the statistical dependence obtained by Kochukhov and Bagnulo according to which the rotation braking (increasing of the rotational period) takes place in the range of small masses of the star-companion.

The observation data from ATNF pulsar catalogue we are used also (atnf.csiro.au). Among 1879 pulsars that are present in the ATNF pulsar catalogue only 141 PSRs enter as companions into binary systems. This are systems with more number of low-mass stars. Only 81 objects having estimation of mass of more than $0.2M_\odot$.

For the low-masses star companion, when $M_{star} << M_{ns}$, the semi-major axis of the system does not increase even in the case of a strong stellar wind from the donor (Fig. 2).

We give the orbital period distribution as a function of the mass of the star-companion on Fig. 3.

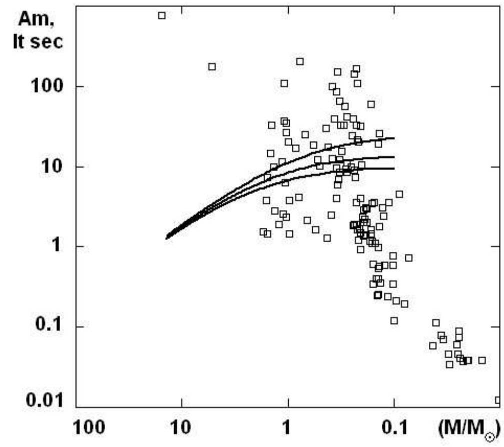

Figure 2: Distribution of the semi-major axis of the binary system (A_m) in the light second units depending on the median mass of the neutron star companion. Solid lines illustrate qualitative behavior under the Jeans mode conditions corresponding to $0.8M_\odot, 1.4M_\odot, 2.0M_\odot$ of neutron star mass (from the top to bottom respectively).

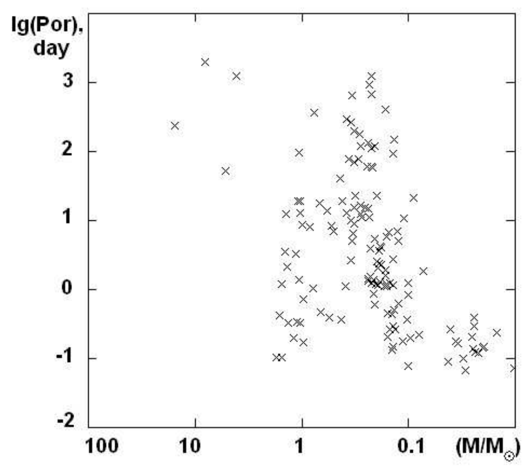

Figure 3: Distribution of the orbital periods (P_{or}) as a function on companion median mass ($M/M_\odot$).

It is possible to assume that in the row of the binary systems in the range of star masses from $0.3M_{\odot}$ to $2M_{\odot}$ the growth of the orbital period can occur (Fig. 3.). Unfortunately, in ATNF catalog is observed the deficit of pulsar companions in the mass range from $2M_{\odot}$ up to $8M_{\odot}$ (it is MCP mass range). It is not give the possibility to make a complete statistical analysis. Figure 3 shows that the behavior with the Jeans mode condition corresponds to another range of masses of the star-companion: $M_{star} \in [0.3M_{\odot}, 2.0M_{\odot}]$.

3. Conclusion

We have adopted the model of MCP stars as a close binary system with undetected neutron star as a companion star. This model explains many properties of MCP stars, in particular: secular decrease of the semi-major axis of the binary systems, statistical distribution of the MCP star orbital periods as a function on their masses, and some others.

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